# Lead consumption of 18- to 36-month-old children as determined from duplicate diet collections: Nutrient intakes, blood lead levels, and effects on growth

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## ABSTRACT

**Objective** To determine the amount of lead ingested in food by means of duplicate diet collections, nutrient intakes, and anthropometric measurements of young children.
**Design** Once a month for a year, data were collected from 24-hour duplicate diets, hand wipes, a dust index, and anthropometric measurements. Quarterly, venous blood samples were obtained. Thermal ionization spectrometry by means of a lead-205 tracer was used to determine lead present in food, blood, and the hand wipes. A dust index was determined on the basis of observation of dust on surfaces in the home. Anthropometric measurements obtained were height, weight, head circumference, and mid-upper arm circumference.
**Subjects/setting** Subjects were 21 children, aged 18 to 36 months, who resided in homes located in an urban area with potentially high lead levels.
**Main outcomes measured** Lead contamination in food and on hands, and blood lead values, were determined.
**Statistical analysis performed** Pearson correlation coefficients were used to determine relationships between lead content in food, blood, and hand wipes and growth. Multiple regression analyses examined the effect of food types and dust lead on lead levels in food, and the effect of these variables on head circumference.
**Results** Mean blood levels were 0.3089±0.1496 µmol/L; 12 samples contained more than 0.4826 µmol/L. Total intake of lead from food was 4.95 µg/day and ranged from 1.10 to –22.10 µg/day. More than a fourth of the diets collected exceeded 6.00 µg/day. Foods considered home prepared were moderately related to blood lead level, and the dust index and hand wipe lead levels were related to total food lead. Home-handled foods, canned foods, and hand-wipe lead were significant predictors of the lead content in food. A negative relationship was found between head circumference and blood lead level.
**Applications** Level of lead in food was directly related to hand-wipe lead. This finding underscores the need for dietitians and other health professionals to stress the importance of cleanliness in environments that are potentially lead contaminated. Appropriate hand washing and surface cleaning should be emphasized when preparing and consuming food. The inverse relationship between head circumference and blood lead levels points to the need for additional studies to validate this finding while controlling for other extraneous variables. *J Am Diet Assoc. 1998; 98:155-158.*


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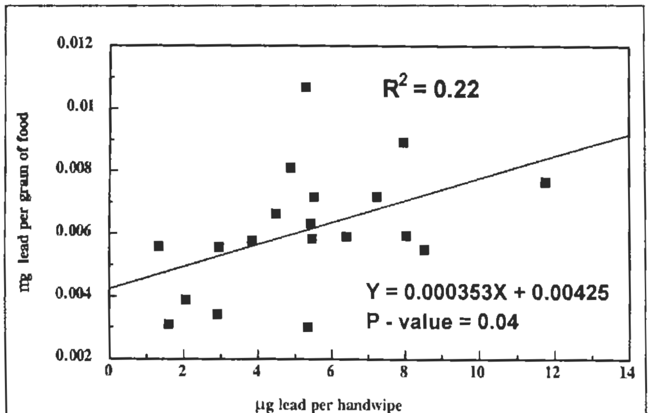
Lead exposure is the most common environmental health problem for children in the United States (1,2). One of every 6 children younger than 6 years of age is exposed to lead at levels that can cause damaging physical and mental effects that may last for years—perhaps for a lifetime (3-18). Lead is transferred in utero and postnatally via respiratory and oral routes: through paint chips, dust containing lead, and diet (19). Mean dietary lead intakes of children are estimated at 90 to 120 µg/day (20,21) with 30% to 50% absorption (22). Reduction in the use of lead-soldered cans has substantially reduced dietary lead intake (23-25). Nevertheless, the risk remains. The main purpose of this study was to examine the presence of lead in weighed, duplicate diet collections of young children.

**Table**
Food categories based on food packaging and amount of handling in preparation and percentages consumed by children

| Categories | % of diet by weight as consumed[a] |
|---|---|
| Home-prepared foods (eg, meat loaf, au gratin potatoes [raw potatoes], cookies [raw ingredients]) | 5 |
| Home-handled foods (eg, lunchmeat, sliced cheese, bananas, peeled apples, cantaloupe) | 13 |
| Reconstituted foods (eg, Kool-Aid[b], frozen juice, rice) | 18 |
| Canned foods (eg, tomato sauce, canned juice, canned green beans, canned soda pop) | 9 |
| Packaged foods (eg, milk, ready-to-eat cereal, soda pop [in liter bottles], juice in bottles, cake [from a mix]) | 40 |
| Frozen foods (eg, ice cream, frozen vegetables, frozen dinners) | 3 |
| **Total** | **89** |

[a]Water consumed accounted for the remainder of the diet.
[b]Kraft, White Plains, NY




*Lead concentrations in food and hand wipes.*

## METHODS

Caregivers of 21 children residing in an urban area with potentially high lead content (26) in Omaha, Neb, were recruited. At the beginning of the investigation, the children were between 18 and 36 months old, the group shown to have the highest levels of lead in blood (15). All resided in well-maintained housing constructed before 1955. The children were not cared for out of the home for more than 20 hours per week.

Caregivers were trained in the procedures of collecting duplicate diets and were provided with an electronic, digital scale for weighing all food and beverages (including water). Monthly, over a 1-year period, each caregiver recorded diet in a diary and collected a 24-hour diet identical to that consumed by the child. A dietitian was present for 1 meal during each 24-hour period to verify accuracy in the collection. During this visit and before meal collection, the dietitian completed a hand-wipe procedure on the child using 2 different wipes (K-Mart Brand Little Ones Baby Wipes, Troy, Mich), one on each hand (27). The wipes were immediately sealed in a lead-free container for later analysis. This component of the project was included to estimate how much lead from the environment was present on the child's hands. After diet collection, the food/water sample was weighed and frozen for later analysis. A phlebotomist collected venous blood quarterly during the study using Sarstedt polypropylene syringes (Sarstedt Co, Arlington, Tex). To assess environmental lead, a monthly dust index was completed. This index was determined on scoring several household surfaces based on the presence or absence of dust. Measurements of height, weight, and head and upper arm circumferences were completed using standardized techniques. Analyses of all samples for lead were completed using thermal ionization, multi-collection mass spectrometry (Finnigan MAT 261, Finnigan instruments, Breman, Germany) by means of a lead 205 tracer (28-31); lead analyses were completed in Dallas, Tex. The spectrometer has 8 collectors, sufficient to allow all isotopes of lead to be measured simultaneously. Quality-control procedures determined that errors fell into 3 categories independent of one another: those inherent in the performance of the mass spectrometer, those resulting from contamination of the sample during processing, and those resulting from errors in the aliquot procedure, the last of these pertaining to the analysis of food. Performance of the mass spectrometer was checked by analyzing the National Institutes of Standards and Technology standard SRM 981, common lead. Contamination levels were monitored by measuring blanks. For blood, these were less than 100 pg lead, which is a negligible fraction of the lead processed. Accuracy of the lead 205 spike calibration and the overall methodology was verified by analyzing the National Institutes of Standards and Technology blood standard, SRM 955a. For hand wipes, the analytic blank was similar to that associated with the blood analyses but was overwhelmed by the lead in the wipes themselves, which averaged 220 ng. Although this figure is large, it is still only 5% of the average amount of lead wiped off the hands. (The brand of wipes used had the lowest lead content of the brands sold in Omaha at the time of the study.) Food samples were homogenized in a 4-L blender (Waring, New Hartford, Conn) and transferred to a 4-L beaker (Pyrex-Corning, Chicago, Ill). Aliquots were obtained by vigorously stirring the homogenate on a magnetic stirrer and siphoning out approximately 10%. Analyses of replicate aliquots showed that lead concentrations were reproducible to better than 10%. The analytic blank associated with the food analyses was about 1 ng lead on account of the large quantity of nitric acid needed to decompose the aliquots.

From the dietary records, the researchers separated all foods and beverages into categories on the basis of the composition of the container and/or handling during preparation. The categories were thought to differentiate sources of lead from canned items, foods requiring minimal handling, and foods requiring more handling in the home, which would be exposed to more environmental contamination. Percentages were determined on the basis of weights recorded in the food diaries. Categories with examples are shown in the Table. Estimated nutrient content of the diets was determined, as this has been shown to be a factor affecting the absorption of lead (32).

Descriptive statistics, multiple regression, and correlations were completed using the Statistical Analysis System (version 6.12, SAS Institute, Cary, NC), and diets were analyzed using the Nutrient Data System (version 2.3, 1991, Nutrition Coordinating Center, University of Minnesota, Minneapolis, Minn). All dietary information was entered and evaluated by one trained technician to eliminate interpersonal judgments. Training and questions were handled by the dietitian.

## RESULTS AND DISCUSSION

Half of the children in the study were from minority ethnic backgrounds; the sample was composed equally of girls and boys. Mean age at the beginning of the study was 25.6 months. Half of the families earned more than $20,000 annually.

Mean lead intake in the duplicate diets was 4.95±3.25 µg/day (1.10 to 22.10 µg), 0.559 µg/100 kcal energy consumed, 0.00606±0.00398 µg lead per gram of food, or 0.419 µg/kg of body weight. Some diets contained more than the 5 to 11 µg estimated in the 1990 Food and Drug Administration Total Diet Study (33), and 65 diets (25%) contained more than 6.0 µg. Separate assays indicated little contribution of lead from the water, which contained an average of 0.22 µg/L. These levels are considered low and should not have contributed much to food categories where water was used in preparation.

Mean lead levels in blood were 0.3089±0.1496 µmol/L[1] (2.50 to 16.20 µg), an amount higher than that determined from data collected in national surveys (34,35). Twelve of the blood samples contained more than 0.4826 µmol/L.

Two subjects were removed from the analysis involving hand wipes because of obvious contamination. Mean lead content was 5.24±4.09 µg per wipe (0.40 to 26 µg). A positive linear relationship was found for subjects between mean lead content of hand-wipe and lead per gram of food ($r$=.47, $P$<.05) (Figure). This relationship may be the result of the caregiver adding lead to the food in handling. It is also likely that the child added lead in handling food during consumption.

A major source of lead exposure for children is dust (36). Researchers have determined relationships between hand dust and blood levels (37,38).

The children consumed approximately 900 kcal energy per day, 83% of the Recommended Dietary Allowance (39). This finding is consistent with those of other researchers who found slightly reduced intakes during the collection of a duplicate diet (40). Collection completeness was confirmed because there was less than a 3% variation between the weights of the food and water in the containers and those recorded by caregivers. Diets were adequate for most nutrients; however, mean intakes of vitamin D (57%), calcium (58%), phosphorus (72%), zinc (46%), and iron (89%) were less than the Recommended Dietary Allowances. Low calcium, zinc, and iron levels have been shown to enhance lead absorption in the small intestine (32).

Percentage of diet by weight contributed by each food category is shown in the Table. Multiple regression analysis was conducted on subject means with lead per gram of food as the dependent variable and hand-wipe lead, the dust index, and the food categories as independent variables. Results indicated that lead levels in hand-wipes ($P$<.05), home-handled food ($P$<.01), and canned food ($P$<.01) were significant predictors and, combined, accounted for 79% of the variation in dietary lead.

Although there have been reductions in the exposure to environmental lead, an estimated 1.7 million young children still have elevated levels of blood lead

When compared with guidelines of National Center for Health Statistics (41), all anthropometric measurements taken at 6 months were typical or between the 25th and 70th percentile. When these measurements were compared with subject mean level of blood lead, a negative relationship was found with head circumference ($r$=−.48, $P$<.027). This relationship was investigated further as others have determined an adversarial effect of lead on growth, including head size (42-45). In an attempt to rule out other factors, gender, race, income, and age were plotted against blood lead levels and head circumference. These variables were ruled noninfluential because the scatter plots remained virtually unchanged. To investigate any effect diet may have had on head circumference, a regression analysis with the logarithm of blood lead level, age, gender, race, income, calcium intake, protein, total energy, and fat as independent variables was calculated. In addition to blood lead level, total energy intake was significantly related to head circumference (β=0.0071, head circumference in centimeters per kilocalorie consumed; standard error=0.0016), which suggests a possible nutritional influence. The model accounted for 71% of the variation in head circumference.

## APPLICATIONS

Although there have been reductions in the exposure to environmental lead, an estimated 1.7 million young children still have elevated levels of blood lead. The cost of a single treatment for lead intoxication is approximately $2,500, and many children need more than one treatment (46). Children accumulate lead from 2 main sources: in utero (if the mother has an elevated lead level) and hand-to-mouth after birth. Approximately 16% has been estimated to come from food and 75% from dust (24). In our study, handling of food may have accounted for up to 40% of lead intake as a result of dust on surfaces (15). The amount of food handling appeared to increase total dietary lead intake to almost 6 µg/day. Dietitians and other health care professionals need to stress the importance of washing hands and cleaning surfaces before preparing, as well as consuming, any food (46). The factor

[1]To convert µmol/L lead to µg/dL, multiply µmol/L by 20.72. To convert µg/dL lead to µmol/L, multiply µg/dL by 0.04826. Lead of 0.05 µmol/L=1.036 µg/dL.

of surface dust should be considered particularly in older houses and those being remodeled, where the presence of lead is a concern.

The negative relationship between head circumference and blood lead level needs to be interpreted with care. Even though delayed growth has been exhibited in animals and human beings (42-45, 47), the effects observed in this study are not definitive. Other factors, (eg, prenatal care, nutrition, genetics) may be responsible for our finding. ■

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